FINANCIAL VIABILITY OF *PENAEUS SETIFERUS* VERSUS *PENAEUS VANNAMEI* WITH CONTINUOUS LIVE HARVESTING AND ONE FINAL HARVEST STRATEGIES IN SOUTH CAROLINA

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Table of Contents

List of Tables

Table **Page**

List of Figures

Figure

SUMMARY

It is anticipated that prospective aquaculturists, investors, and perhaps lending institutions and policy makers will desire information on the financial feasibility of producing indigenous *Penaeus setiferus* versus specific pathogen free *Penaeus vannamei*. This report was undertaken to provide an accurate and objective picture of the profit or loss from farming these species. In addition, an evaluation is made of the effects of a continuous live harvesting strategy versus a single final harvest strategy on the profitability of the two species.

The hypothetical shrimp farm described in this report includes 24 ponds, each 1 hectare in size, located on 31 hectares of land that is leased near a saltwater source. The base scenario assumes one final harvest strategy, stocking density of 80 postlarvae/meter^2, an aggregate survival rate of 70%, and a price of \$4.95/kg for *P. vannamei* and \$4.73/kg for *P. setiferus*. The effects of alternative stocking densities, survival rates, prices, and live harvesting are investigated in 7 other scenarios. All the 8 scenarios assume a feed conversion rate of 2:1, and the length of the grow-out cycle as 5 months.

Initial investment in facility and equipment is approximately \$1 million. Because of differences in growth rates and resulting feed costs, total initial investment for both constructing and operating the facility depends on species produced. In the base scenario, total initial investment including operating costs, for *P. vannamei* is \$1.38 million and for *P. setiferus* is \$1.35 million[1]. After the third year, when the farm produces at full capacity, net cash flow after estimated taxes for *P. vannamei* is \$250,000 and for *P. setiferus* is \$103,000.

The ten-year (after tax) internal rate of return (IRR) for *P. vannamei* is 15.1%. The projected IRR is greater than the assumed base-scenario after-tax discount rate of 10% for *P.vannamei*. However, the projected IRR for *P. setiferus*, -4.9%. This is less than the base-scenario discount rate. Net present value (NPV) in ten years for *P. vannamei* is \$232,000 and for *P. setiferus* is a negative \$568,000. The negative NPV indicates that at current prices, technology, and the assumed discount rate, *P. setiferus* is <u>not</u> profitable.

The IRR and NPV are highly sensitive to the assumed stocking densities, survival rates and expected prices at harvest. Given a discount rate of 10%, small changes in stocking densities, survival rates and prices can result in large losses even for a *P. vannamei* shrimp farm. However, continuous live harvesting has positive effects on net cash flows. Because of the limited market for live shrimps, producers should remain alert for over-supply conditions that can have a negative impact on prices. With continuous live harvesting, IRR increases to 16.4% for *P. vannamei* and to 2.2% for *P. setiferus*. Even with continuous live harvesting, *P. setiferus* remains an unprofitable enterprise.

Commercial shrimp farms utilizing specific pathogen free *P. vannamei* postlarvae (PL) can be profitable in South Carolina. Farms can have larger profits by practicing continuous live harvesting strategies. However, the indigenous *P. setiferus* is not profitable. Therefore, regulatory actions that hinder the import of specific pathogen free *P. vannamei* PL from out-of-state hatcheries could have adverse impacts on the South Carolina commercial shrimp farms.

INTRODUCTION

In 1993, 26 farms in South Carolina, Hawaii and Texas produced a record crop of farm-raised shrimp, approximately 2,500 metric tons, 25% more than the estimated 2,000 tons in 1992 (Rosenberry, 1993). However, the United States remained a relatively small producer of farm-raised shrimp, accounting for less than 2% of the production

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[1]This assumes operating at 50% of full capacity in year 1.

in the Western Hemisphere. In 1993, South Carolina with 14 farms and about 100 hectares (ha) in commercial production, accounted for approximately 20% of the nation's cultured shrimp output (unpublished data, S.C. Department of Natural Resources, 1994).

The profitability of South Carolina's (SC) shrimp mariculture industry is dependent on many factors including the availability of viable postlarvae (PL) at a competitive price. The SC farms have been generally dependent on out-of-state suppliers for PL of the species of choice, *P. vannamei*, a non-indigenous marine shrimp (Rhodes, et al. 1992). However, farmers have become apprehensive about future supply and quality of imported PL. In 1989, many farms had to reduce planned stocking densities and/or not stock all their ponds due to an apparent shortage of quality PL's (McGovern-Hopkins et al. 1991). In addition, environmental concerns have increased in recent years regarding the perceived impacts of farming non-indigenous shrimp in the United States. Industry awareness has also increased relative to possible negative impacts of shrimp diseases carried by PL from out-of-state hatcheries. Consequently, as concerns have increased, research has been conducted to evaluate the financial feasibility of producing commercial quantities of indigenous *P. setiferus* versus specific pathogen-free *P. vannamei* in South Carolina. In addition, the effects of continuous live harvesting versus one final harvest on the profitability of the two species is evaluated. The information in this report should be of use to prospective aquaculturists, investors, and perhaps lending institutions and policy makers.

Capital budgeting decisions, i.e., all actions relating to the planning and financing of capital outlays for the purpose of purchasing equipment and facilities, are a key factor in the long-term profitability of the shrimp farm. In this study, discounted cash flow analysis, one of the financial tools that is used to aid an investor in making wise capital budgeting decisions, is used to compare the profitability of *P. setiferus* versus *P. vannamei* and continuous live versus one final harvesting strategies. The application of financial feasibility analysis of aquaculture projects, including discounted cash-flow technique, is discussed in Rhodes (1991).

LITERATURE REVIEW

Sandifer, et al. (1993) conducted pond experiments at Waddell Mariculture Center to compare production characteristics of the native *P. setiferus* and Pacific *P. vannamei* white shrimp in South Carolina. The production levels achieved in 1989 are thought to be among the highest achieved with *P. setiferus* in pond culture. Their results suggest that *P. setiferus* may be a viable alternative to *P. vannamei* for intensive cultivation in the continental U.S. when *P. vannamei* are unavailable. They suggest that further evaluation of this potential is needed.

Griffin, et al. (1984) used a conceptual model that included production, engineering, marketing, environment and profit as submodels and a bioeconomic factors simulation model to evaluate a projected penaeid shrimp maricultural operation on the Texas coast. The results showed that the operation would prove marginally economically feasible based on assumptions of the study. A 2% chance of loss and a 4.5% annual return on investment were predicted by using baseline simulations.

Adams, et al. (1980) developed a bioeconomic engineering model for shrimp mariculture systems for a hypothetical grow-out operation in Brazoria County on the northern Texas coast. A budget simulation was developed to examine economies of size. Budgeting and cash-flow statements were used to examine penaeid shrimp mariculture systems. Their results suggest that the size of the individual pond which captures most economies of size is 2.5 acres and the number of ponds which achieves most of the economies of size for the firm is 24. For this operation, IRR to total investment is 17%.

Hollin and Griffin (1985) examined the economics of: (1) growing one crop of large shrimp per year versus two crops of medium size shrimp, and (2) small, intensive ponds versus large, semi-intensive ponds. The after-tax internal rate of return (IRR) in the base scenario for the 500 acre system was 14.61% and for the 40 acre system was 9.1%. When the production strategy was changed from one crop to two crops, the IRR on the 500 acre system increased to 22.8%. The most significant change in the IRR was brought about by increasing the survival rates. When the survival rate was increased from 50 to 70%, IRR increased from 14.6 to 25%.

Pardy, et al. (1983) estimated density dependent growth equations for two species of penaeid shrimps, *P. stylirostris* and *P. vannamei*. Based on these equations, a simulation model was developed to examine the effects of alternative stocking densities and cropping schemes on various variables including gross revenue and revenue above total selected costs. They found that the one harvest production strategy resulted in the greatest gross revenue, no matter what stocking densities were chosen. The one crop system generally results in larger shrimp and thus, greater market price and higher revenue above selected costs.

Griffin and Lambregts (1993) evaluated the effects of pond design (pond size, pond shape, levee crown size and canal bank slope) on the after-tax IRR of a 40 ha shrimp farm. Regression analysis was used to examine the relationship between pond design variables and the IRR. Results suggest that pond shape, followed by pond size, were the most influential variables. An increase in pond size from 2 to 10 ha increased IRR from 17.2 to 21.3%. The results are specific to the design, size of the farm and soil type and therefore, can not be extrapolated outside the analyzed designs. The authors also addressed the possibility of increasing operating risks associated with large ponds.

Hanson, et al. (1985) analyzed the effects of 12 different facility sizes on the profitability of producing a single species of shrimp, *P. stylirostris*. Stochastic processing of the model permitted random fluctuations in prices, production, weather and survival rates within their probability density functions. However, risks associated with larger pond sizes are not examined. The results suggest that increased sizes of total facilities and pond size generally increase IRR. For example, a 40 ha facility with 4 ha ponds had a mean after-tax IRR of 0.75%, while a 400 ha facility with 20 ha pond sizes had a mean IRR of 13.31%.

METHODS AND DATA

The hypothetical farm described in this paper is based on recommended best management practices. Production and cost estimates are predicated upon experience at Waddell Mariculture Center (WMC), South Carolina commercial shrimp farms and vendors of supplies and services to the aquaculture industry. Other agencies, such as USDA-Soil Conservation Service, U.S. Army Corps of Engineers, and S.C. Department of Health and Environmental Control, provided data on pond construction costs, licenses, permits, etc.

Facility Design and Equipment

The hypothetical facility analyzed in this report consists of 24 ponds each of 1 hectare in size constructed on a 31 hectare farm that is leased near a saltwater source. The average pond depth is 1.3 m. A 3-m levee (wide enough for service vehicles) separates each pond. It is assumed that the use of the land was to grow row crops and consequently there are few stands of trees.

Water exchange is made available to improve water quality (such as dissolved oxygen and water temperature). A minimum water exchange rate of 5% is used in this study. However, the farm has the capacity to exchange a maximum of 20% of the water in any one pond. Therefore, the farm has six pumps with flow ratings of 9.1 m^3 of water per minute and 25 horsepower motors. A 12 m levee separates each pond from the fill and the discharge canals (Figure 1). The fill canal water will be gravity fed into each pond via an intake riser and released through a discharge riser into the discharge canal (Figure 1). These risers regulate water flow with a system of boards. Two 10-horsepower paddle-wheel aerators will be placed in each pond. All electrical wiring for pumps and aerators will be 3 phase.

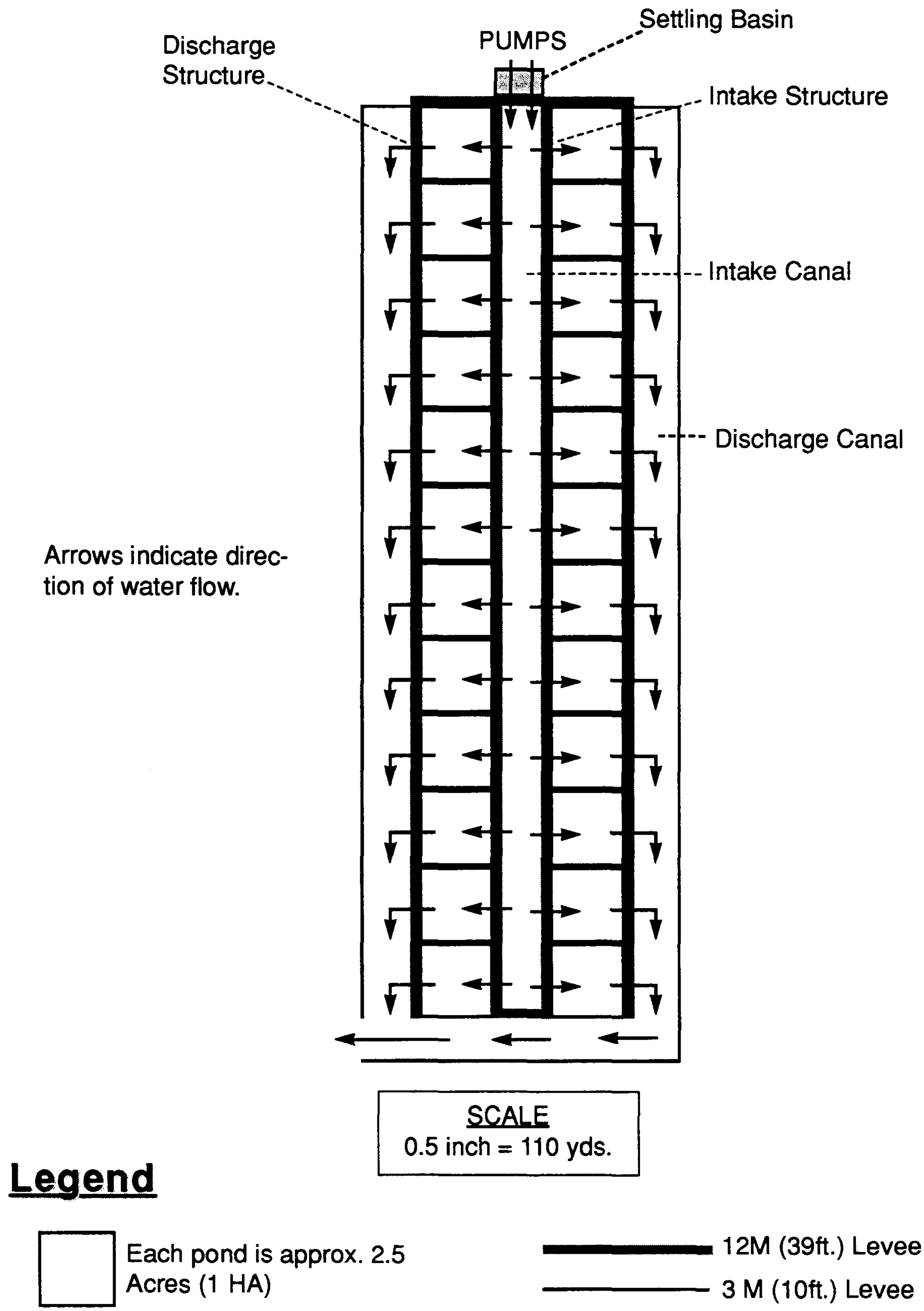

Figure 1 - Hypothetical Shrimp Farm Design (Gravity Feed Water System)

Other facilities and equipment include: (1) an office trailer, (2) a 1,000 square feet lab/shop, (3) a 2,000 square feet warehouse, (4) three medium sized silos each holding 50,000 pounds of feed, (5) one longbed pickup truck and one flatbed truck, (6) one 23 horsepower tractor for light work and towing feeder and one 52 horsepower tractor for canal and pond maintenance, (7) one feed blower, (8) one ice machine, (9) harvest, office, lab equipment, and (10) pre-start up project and survey reports.

Production Assumptions

Specific pathogen free (SPF) *P. vannamei* is used in this study. SPF *P. vannamei* became available for distribution to the United States in 1989 (Wyban, et al. 1993). It has been found that use of SPF *P. vannamei* has increased survival rate, feed efficiency, production and profitability for the shrimp industry (Wyban, et al. 1992).

The length of grow-out cycle is 5.0 months. Risks associated with growing shrimp include natural disasters nutritional and environmental factors, such as low quality feed, poor water quality, pollution, and associated low dissolved oxygen events. The risks of growing shrimp are not examined in this study. A feed conversion rate of 2.0:1 is used in this study. The harvest weight is estimated using a density dependent growth model (see Appendix 1). This growth model was estimated using data collected at Waddell Mariculture Center and adjusted for commercial grow-out experience.

Major Financial and Operating Assumptions

The major financial and operating assumptions are the following: (1) the price of PL including transportation is $10.00 per 1,000; (2) cost of feed (F.O.B., farm site) is $0.55 per kilogram (kg); (3) electricity cost is $0.07/kilowatt-hour(kwh); (4) discount rate is 10%; (5) planning horizon is 10 years; (6) initial investment starts in year 0, first year output is 50% of maximum capacity, second year output is 75% of maximum capacity, and third year onwards production is at 100% of capacity; and (7) the actual operating time is a six month season. The straight-line depreciation method is used. A business manager, a technical manager, a clerk/typist/receptionist and two pond management and maintenance crew work full time. Part time employees are a security officer, and harvest and other seasonal labor. It is also assumed that this hypothetical facility is not funded by debt capital, i.e., no loans. The annual financial projections for this facility are generated using a Lotus 1-2-3 spreadsheet template prepared by Applied Analysis, Inc. (AAI), (Leung and Rowland, 1989). The model does not account for natural disasters such as droughts, hurricanes, etc.

Production Scenarios

In the base scenarios, Scenario S and S2A, ponds are stocked at 80 PL/m^2 in late April. An aggregate survival rate of 70% is assumed. Based on the growth model, harvest weights for *P. vannamei* and *P. setiferus* were estimated. In addition, it is assumed that all shrimps are produced for normal market sales, i.e., no live shrimp sales. These shrimps are sold head-on to individuals, restaurant distributors, and wholesalers. Prices are those that prevailed in South Carolina in 1993 for the estimated harvest weights.

The following 7 scenarios for the two species are developed to evaluate the effects of alternative stocking densities, survival rates, and prices[2] (see Table 4):

Scenario S: Stocking density of 80 PL/m^2, aggregate survival rate of 70%, price of $4.95/kg for *P. vannamei* and $4.73/kg for *P. setiferus*

Scenario S1A: Stocking density of 60 PL/m^2, aggregate survival rate of 70%, price of $4.95/kg for *P. vannamei* and $4.73/kg for *P. setiferus*

[2]1994 prices reported by SC shrimp producers were significantly higher than 1993 prices.

Scenario S1B: Stocking density of 100 PL/m^2, aggregate survival rate of 70%, price of $4.95/kg for *P. vannamei* and $4.73/kg for *P. setiferus*

Scenario S2A: Stocking density of 80 PL/m^2, aggregate survival rate of 70%, price of $4.73/kg.

Scenario S2B: Stocking density of 80 PL/m^2, aggregate survival rate of 70%, price of $5.28/kg.

Scenario S3A: Stocking density of 80 PL/m^2, aggregate survival rate of 65%, price of $4.95/kg.

Scenario S3B: Stocking density of 80 PL/m^2, aggregate survival rate of 75%, price of $4.95/kg.

Another scenario, Scenario S4 (see Table 4), evaluates the effects of live harvesting on IRR and NPV. The marketing experience of S.C. shrimp growers have shown that these buyers are seafood distributors or "live haulers" selling to Oriental restaurants in the Northeastern United States (Rhodes, et al. 1994). The projected aggregate demand for live marine shrimp by restaurants in the continental U.S. is quite small, approximately 30% of the 1993 U.S. farmed shrimp production. Therefore, in Scenario S4, only 5% of production is assumed as live marketed. When harvesting shrimp for live shrimp buyers, it is assumed that labor costs $200 for a 250 kg shipment. In this analysis, no other changes in operating costs are associated with live shrimp marketing.

RESULTS

Base Scenarios

Initial investment in facilities and equipment is $998,000 (Table 1). Equipment costs were approximately 49% of this cost. Land clearing and construction costs account for approximately 48%.

Due to differences in growth rates and resulting feed costs, operating costs depend on species produced. For *P. vannamei*, operating cost in year 1 is $0.38 million. Therefore, *P. vannamei* requires a total initial investment of $1.36 million before any revenue from sales is received. For *P. setiferus*, projected operating cost in year 1 is $0.35 million with a total initial investment of $1.33 million.

A simple, pro forma annual income statement for operating years three through ten was generated for the hypothetical *P. vannamei* shrimp farm (Table 2). Projected annual sales are $1.11 million at full capacity and total cash operating cost is $0.77 million. Feed and PL accounted for the largest percentage of operating cost, 33% and 25%, respectively. Energy accounted for 10% of the operating cost. Total annual cash outflow is $0.86 million. Net cash flow after taxes is $0.25 million.

The ten-year (after estimated income taxes) internal rate of return (IRR) and net present value are projected. The ten-year IRR is 15.1% (Table 2), which is greater than the base-scenario after-tax discount rate of 10%. Net present value (NPV) in ten years is projected to be $232,000.

The pro forma annual income statement for operating years three through ten for a hypothetical *P. setiferus* shrimp farm in South Carolina was generated (Table 3). Projected annual sales are $0.81 million. Total cash operating cost is $0.71 million. Feed and PL accounted for the largest percentage of projected operating cost, 27%. Energy accounted for 12% of the operating cost. Total annual cash outflow is $0.71 million. Net cash flow after taxes is $0.10 million.

The ten-year IRR is negative 4.9% and NPV is negative $568,000. The negative NPV for *P. setiferus* indicates that this operation will <u>not</u> generate a positive return on equity if all shrimp are used for normal market sales. Unless prices rise above $5.48 per kg, an increase of approximately 16% above levels for 1993, producing *P. setiferus* will not be profitable based upon this analysis. In contrast, the positive NPV for *P. vannamei* shows the potential profitability of culturing this species. Prices in 1993 are approximately

Table 1. Summary of Facility and Equipment Costs for a Hypothetical Shrimp Farm in South Carolina, 1993.

Item	Cost	Percent[1]	Useful Years
DEVELOPMENT COST			
Project Report 10,000		20	
Project Manager	20,000		
Subtotal	$ 30,000	3.0	
LAND CLEARING AND FACILITIES			
Land Clearing 85,800		20	
Pond Construction	180,000		10
Discharge and Intake System	96,000		10
Buildings	44,000		20
Other	71,955		
Subtotal	$ 477,755	47.9	
EQUIPMENT			
Harvest Equipment	15,000		10
Feed Storage Bins	36,000		10
Paddlewheels	240,000		5
Trucks/Tractors	50,000		5
Feeding System	40,500		5
Power Equipment	11,000		10
Pumps	82,800		5
Other	15,000		
Subtotal	$ 490,300	49.1	
TOTAL COSTS	$ 998,055	100.0	

[1] Percent of total cost

Table 2. Projected Annual Income Statement for Operating Years Three Through Ten, and Discounted Cash Flow Analysis in the Base Scenario for a Hypothetical *Penaeus vannamei* Shrimp Farm in South Carolina.

Item	Value or Cost (In Thousands)	Percent[1]
Projected Annual Sales (223,910 kilograms at $4.95/kg)	$ 1,108	
Projected Annual Expenses		
Juveniles	192	25
Feed	252	33
Energy	80	10
Lease Rent	60	8
Labor	59	8
Salaried Personnel	83	11
Contingency	8	1
Other	33	4
TOTAL OPERATING COST	$ 767	100
Projected Depreciation	129	
Total Operating Costs with Depreciation	897	
Projected Taxable Income (Sales Minus Total Operating Costs)	212	
Taxes (Federal and Local)	79	
Income After Taxes (Taxable Income Minus Taxes)	132	
Total Annual Cash Outflow (Total Operating Costs plus Taxes)	847	
Net Cash Flow (Sales Minus Annual Cash Outflow)	262	

Discounted Cash Flow Analysis:

	10 years
Net Present Value (dollars 000's) at 10%	232
Internal Rate of Return (percent)	15.09%

[1]Percentage of total operating cost.

Table 3. Projected Annual Income Statement for Operating Years Three Through Ten, and Discounted Cash Flow Analysis in the Base Scenario for a Hypothetical *Penaeus setiferus* Shrimp Farm in South Carolina.

Item	Value or Cost (In Thousands)	Percent[1]
Projected Annual Sales (171,226 kilograms at $4.73/kg)	$ 810	
Projected Annual Expenses		
Juveniles	192	27
Feed	192	27
Energy	80	12
Lease Rent	60	8
Labor	59	8
Salaried Personnel	83	12
Contingency	7	1
Other	33	5
TOTAL OPERATING COST	$ 706	100
Projected Depreciation	129	
Total Operating Costs with Depreciation	837	
Projected Taxable Income (Sales Minus Total Operating Costs)	-28	
Taxes (Federal and Local)	-6	
Income After Taxes (Taxable Income Minus Taxes)	-22	
Total Annual Cash Outflow (Total Operating Costs plus Taxes)	702	
Net Cash Flow (Sales Minus Annual Cash Outflow)	107	

Discounted Cash Flow Analysis:

	10 years
Net Present Value (dollars 000's) at 10%	-568
Internal rate of return (percent)	-4.93%

[1]Percentage of total operating cost

18% greater than the break even price. That is, prices of *P. vannamei* can drop approximately 18% and the producers will continue to make a positive NPV.

Alternative Scenarios

P. setiferus is unprofitable (i.e. a negative NPV) in all the alternative scenarios considered in this analysis (Table 4). The profitability of *P. vannamei* is sensitive to changes in prices, stocking densities and survival rates.

In scenario S4, 5% of the shrimp are live marketed. Discounted cash flow analysis for *P. vannamei* and *P. setiferus* with 5% of production for live market sales and the remaining 95% of production for final market sales were generated (Table 4). For *P. vannamei,* the ten-year IRR is 16.9%, which is greater than the base scenario after-tax discount rate of 10%. NPV in ten years is $321,000. The higher IRR and NPV in Scenario S4, as compared to the base scenario where 100% of the shrimp are for normal market sales, indicates the potential higher profitability of selling shrimp to "live-haulers". For *P. setiferus*, IRR is 2.2%, but the NPV is still a negative -$320,000. Relative to the base scenario, live harvesting does improve the financial viability of a *P. setiferus* shrimp farm. However, the negative NPV still indicates that this operation would not generate a positive return on equity even if 5% of the shrimps are used for live market sales.

DISCUSSION

Sandifer, et al. (1993) evaluated production data from Waddell Mariculture Center (WMC) and concluded that *P. setiferus* may be a viable alternative to *P. vannamei* for intensive cultivation in the continental U.S. when *P. vannamei* are unavailable. They recommended further evaluation of this potential. The preliminary financial analysis presented in this report suggests that a *P. setiferus* commercial shrimp farm operation would only generate a negative IRR. This is less than the range of IRR estimated by other researchers for farms of similar sizes. The estimated IRR's range from 0.75% by Hanson, et al. (1985) for a 40 ha facility to 4.5% by Griffin, et al. (1984). The IRR of 9.06% estimated by Hollin and Griffin (1985) is with a survival rate of 50%, less than that assumed in this study.

The estimated IRR for *P. setiferus* is less than the assumed discount rate for the base scenario. Therefore, this operation fails to generate a positive return on equity. The negative NPV may be improved if better growth can be achieved and/or by developing a specialty market for *P. setiferus*. Relatively high growth rates have been recorded for this species in the wild or at relatively low densities in ponds (Sandifer, et al. 1993 and WMC unpublished data). Achievement of these growth rates in intensive pond culture will depend on improved diets and/or rearing procedures for *P. setiferus*. Live shrimp market segments for fishing bait are limited to native species. Although wholesale bait shrimp prices may be somewhat higher, there is a potential risk of "flooding" this relatively limited market. In addition, the lack of cost effective storage facilities may hinder entrance to these markets.

The projected IRR for *P. vannamei*, 15.1%, is greater than the assumed base scenario discount rate of 10%. The positive NPV for *P. vannamei* indicates that commercial shrimp farms in S.C. could have a positive return to equity assuming specific pathogen free PL are used. Hollin and Griffin (1985) estimated an IRR of 22.5% for a 40 acre farm with an 80% survival rate, a survival rate 10% points higher than used in the base scenario in this analysis. The NPV for both species may be improved by operating larger facilities, integrating a nursery "headstart" operation with the farm or if price increases.

The profitability of Pacific white shrimp, *P. vannamei* and the negative NPV of indigenous *P. setiferus* have implications on regulations that might affect the import of PL from out-of-state. Regulations that exclude *P. vannamei* as the target species could severely

Table 4. Discounted Cash Flow Analysis for the Alternative Scenarios for Hypothetical *Penaeus setiferus* and *Penaeus vannamei* Shrimp Farm in South Carolina, 1993.

Scenarios	*P. setiferus*		*P. vannamei*	
	NPV	IRR (%)	NPV	IRR (%)
Scenario S	-$416,000	-0.40%	**$232,000***	**15.09%***
Scenario S1A	-$843,000	-14.92%	-$275,000	3.40%
Scenario S1B	-$166,000	6.11%	$516,000	20.84%
Scenario S2A	**-$568,000***	**-4.93%***	$87,000	11.95%
Scenario S2B	-$201,000	5.26%	$438,000	19.31%
Scenario S3A	-$600,000	-5.96%	$55,000	11.25%
Scenario S3B	-$236,000	4.40%	$402,000	18.60%
Scenario S4	-$320,000	2.22%	$321,000	16.94%

***BASE SCENARIO**

Scenario S	Stocking density of 80 PL/meter^2, aggregate survival rate of 70%, price of $4.95 / kg.
Scenario S1A	Stocking density of 60 PL/meter^2, aggregate survival rate of 70%, price of $4.95 / kg for *P. vannamei* and $4.73 / kg for *P. setiferus*
Scenario S1B	Stocking density of 100 PL/meter^2, aggregate survival rate of 70%, price of $4.95 / kg for *P. vannamei* and $4.73 / kg for *P. setiferus*
Scenario S2A	Stocking density of 80 PL/meter^2, aggregate survival rate of 70%, price of $4.73 / kg.
Scenario S2B	Stocking density of 80 PL/meter^2, aggregate survival rate of 70%, price of $5.28 / kg.
Scenario S3A	Stocking density of 80 PL/meter^2, aggregate survival rate of 65%, price of $4.95 / kg.
Scenario S2B	Stocking density of 80 PL/meter^2, aggregate survival rate of 75%, price of $4.95 / kg.
Scenario S4	Stocking density of 80 PL/meter^2, aggregate survival rate of 70%, continuous live market sales of 5% and "normal" market sales of 95%.

NPV = Net present value after taxes.
IRR = Internal rate of return after taxes.
After-tax discount rate is 10%.

constrain the profitability of shrimp farming using the techniques outlined in this analysis.

Continuous live market sales have positive effects on net cash flows for *P. setiferus* and *P. vannamei*. A 1993 survey conducted by Rhodes, et al. (1994) suggests that opportunities for selling live shrimp probably exist throughout the major metropolitan areas of continental U.S., especially in the Northeastern states, but the lack of cost effective storage facilities may hinder entrance to these markets. In addition, the live shrimp market for S.C. producers seems relatively small. Unless additional markets are identified, live harvesting of large quantities of shrimps can have a negative impact on prices. Therefore, because the live shrimp market is relatively small, it is important that producers remain alert for potential "oversupply" conditions that might signal a major reduction in prices, particularly for live market sales.

This study confirms the findings in Rhodes, et al. (1987) that the profitability of S.C. marine shrimp operations is strongly influenced by survival rates, stocking densities, etc. The effects of these variables on the financial viability of producing *P. setiferus* and *P. vannamei* were examined by developing alternative scenarios. The models used in this study are based on several simplifying assumptions, e.g., the land is leased. Nevertheless, in general, the model did demonstrate potential species effects on the direction of changes in profits, and to a lesser extent, the magnitude of such profits. Therefore, it may be fruitful for prospective shrimp aquaculturists, investors, and perhaps lending institutions and policy makers to be aware of these findings.

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APPENDIX 1

SHRIMP HARVEST WEIGHT MODEL

The empirical specification of the model is:

LWeight = b_0 + b_1 LAge + b_2 LDensity + b_3 Species + b_4 Disease + b_5 Year 87 + b_6 Year88 + b_7 Year89 + b_8 Year90 + b_9 Year91 b_{10} Year92 + e .

Where, LWeight = Log of average harvest weight in grams per week, LAge=Log of the number of growout days in weeks; Disease = binary variable, equal to 1 if signs of viral infection were observed during the growout cycle (0 otherwise); Species = binary variable, equal to one if species is P. vannamei (0 otherwise); and LDensity = Log of stocking density, number stocked/m^2 Year87,...,Year92 = binary variable, equal to one for that year, (0 otherwise).

There were a total of 100 observations (ponds) in the data collected at Waddell Mariculture Center during shrimp culture experiments conducted from 1984 to 1992. Each observation had 18 variables (Pond, year, stock date, harvest date, crop length, stock weight, harvest weight, growth rate, pond size, species, stock source, disease status, stocking density, number stocked, number harvested, estimated survival rate, production, and experimental comparison). The biweekly sampling data were excluded from the analysis. Among the 100 observations 45 ponds satisfied the criteria similar to the best management practices recommended for S.C. commercial shrimp farms.

The selected criteria are: a) survival rate greater than 60%; b) density between 20 and 100 per square meter; c) ponds were stocked before June 1; d) ponds were harvested late September or October; e) all aeration rates were included; f) all exchange rates were included; g) ponds in which shellfish were cultured with shrimps were included.

The estimated regression coefficients are presented in Table 5. Significance of the estimated coefficients were tested at 0.05 and 0.1 levels. Three criterion were used to examine the overall "goodness" of fit of the regression models. The high F-value rejects the null hypothesis that all the regression coefficients for the explanatory variables are simultaneously equal to zero. The R^2 and the adjusted R^2 indicate that a large percentage of the variation in the dependent variable are explained by the independent variables included in the model. The adjusted R^2 takes into account the number of explanatory variables in relation to the number of observations. Therefore, in a multiple regression model, the adjusted R^2 is preferred to R^2.

As expected, age and species have a positive effect on the final harvest weight of shrimps. A 1 % increase in age will increase the harvest weight by 0.52 %. Species, a binary variable, with a value of 1 for *P. vannamei* and 0 otherwise, increases the intercept for the regression model for *P. vannamei*.

Density and disease have a negative regression coefficient. That is, as expected, at higher densities the average harvest weight would be smaller. The results show that a 1% increase in density will decrease the harvest weight by 0.16% Disease, a binary variable, with a value of 1 for post larvae with disease and 0 otherwise, will reduce the intercept for the model *P. vannamei* with disease by the estimated coefficient.

Binary variables, one for each year from 1987 to 1992 were included as a proxy for water temperature. To avoid problems with multicollinearity, the year 1986 is omitted and its effects are captured by the intercept. All the YEAR variables shift the intercept by the amount of the estimated coefficient.

Table 5. Regression Coefficients for the Harvest Weight Model[a,b]

Variable Name	Coefficients
Intercept	0.62*
Age	0.52*
Density	-0.16*
Species	0.13*
Disease	-0.07**
Year87	-0.05
Year88	0.07
Year89	0.18*
Year90	0.15*
Year91	0.12*
Year92	0.01

* Variables significant at 0.05 level
** Variables significant at 0.10 level

[a]Harvest weight model adjusted for commercial grow-out experience in *Penaeus vannamei:* Lweight = 0.85 + 0.52 LAge - 0.16 L Density.
[b]*Penaeus setiferus:* Lweight = 0.75 + 0.52 LAge - 0.16 L Density.